

The R-Parity Violating MSSM at Colliders: Philosophy and Benchmarks

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J. Berger, JAE, J. Hirschauer, K. Kaadze, Y. Kats, A. Lath, M. Walker, L. Wang
(F. Garberson, A. Katz, D. Miller, B. Tweedie – Top RPV)

R -parity Violation (RPV) Motivation

- ▶ R -parity is **nice**: B and L conservation, DM candidate
- ▶ But R -parity is **unnecessary**: e.g., \mathcal{B} or \mathcal{L} only, other DM sector

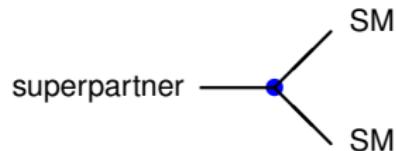
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R -parity violation \Rightarrow LSP can decay

- ▶ Cascade decays without E_T
- ▶ 2-body, 3-body resonances (+ other objects), often in pairs
- ▶ Many, many final states: jets-only to multi-leptons
- ▶ Violation of lepton flavor universality
- ▶ Small couplings \Rightarrow decays can be displaced
- ▶ Very large couplings \Rightarrow possible to produce single superpartners

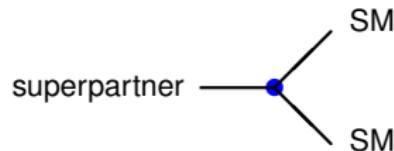
RPV Interactions



$$W = \frac{1}{2} \lambda_{ijk} L_i L_j E_k^c + \lambda'_{ijk} L_i Q_j D_k^c + \frac{1}{2} \lambda''_{ijk} U_i^c D_j^c D_k^c + \mu_i L_i H_u$$

i, j, k = generation indices

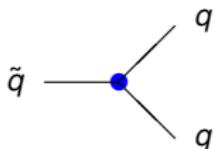
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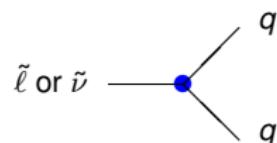
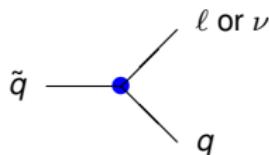
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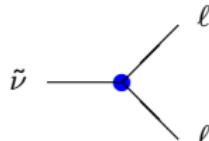
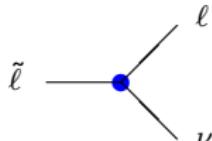
UDD



LQD



LLE



RPV Topologies

What is possible?

Two types of collider signatures:

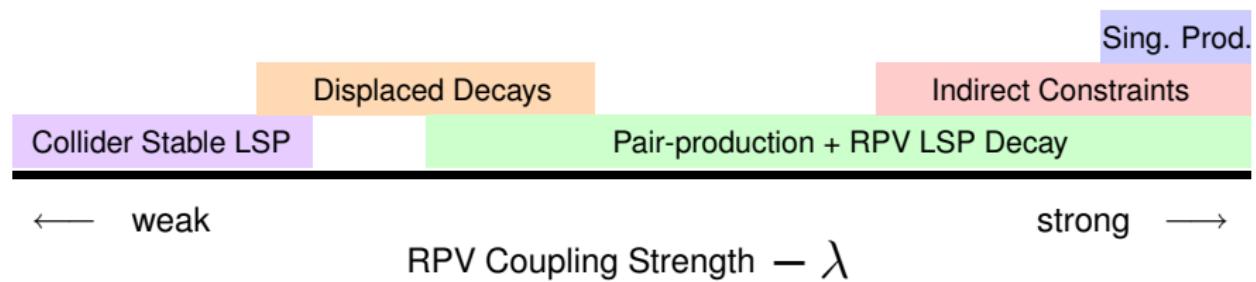
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2. {Single Production} \otimes {Decays} \otimes {All RPV LSP Decays}

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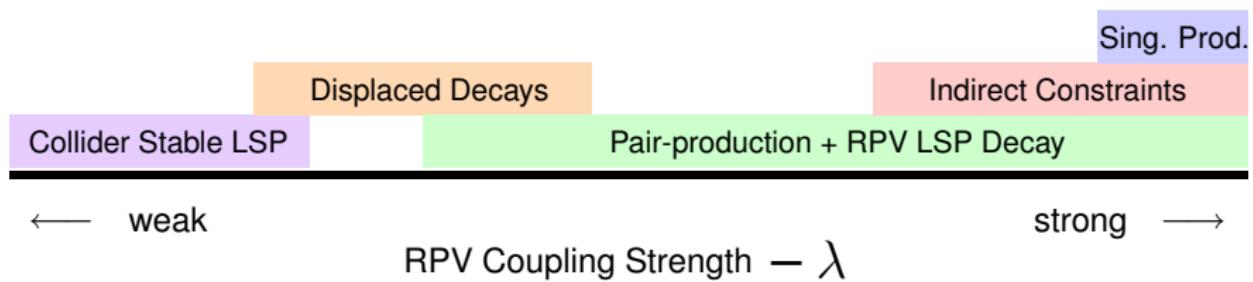


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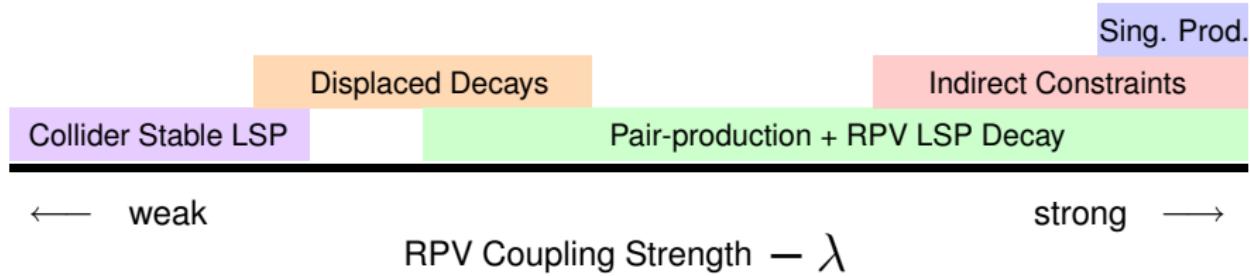
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Single Coupling Dominance



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	Gluino	~	1500 GeV
Naturalness \Rightarrow	Two Stops, One Sbottom	~ ~ ~	700 GeV
	Higgsino	~ ~ ~	300 GeV

Sleptons? Sneutrinos? Bino? Wino?

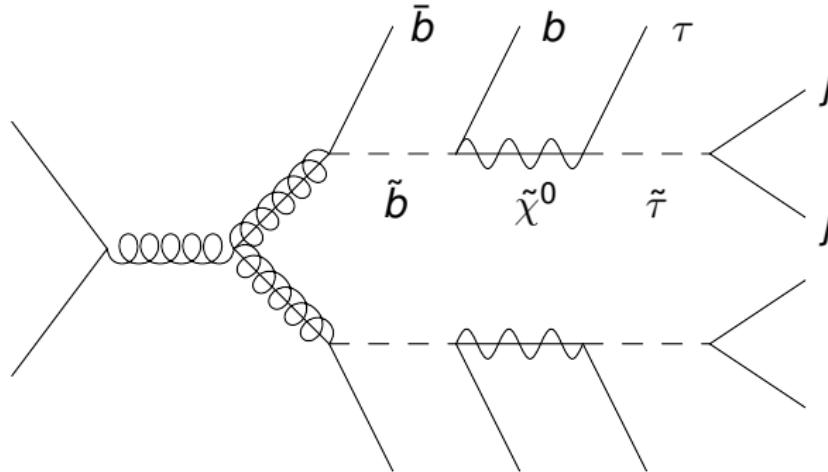
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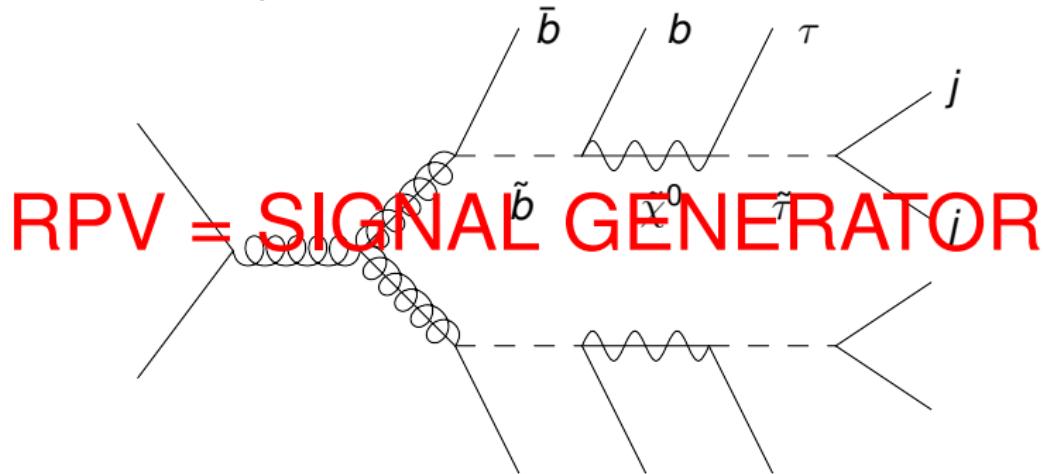
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Collider Reach

What can be said?

TOO MANY MODELS!!!

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Apply a “broad strokes” approach to assess reach ...

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Apply a “broad strokes” approach to assess reach ...

<i>LLE</i>	\Rightarrow	Many leptons & neutrinos	EASY
<i>LQD</i>	\Rightarrow	$\ell\ell, \ell\nu,$ or $\nu\nu$ + many jets	MEDIUM
<i>UDD</i>	\Rightarrow	No Leptons or \cancel{E}_T (unless up cascade)	HARD
<i>LH</i>	\Rightarrow	EW Bosons + \cancel{E}_T (like GMSB)	MEDIUM

Motivated Benchmark Models

by Naturalness, 3rd Generation Dominance and Variety of Final States

Coupling	Production	Final States	Search	Nat.	3G
LLE122	$\tilde{g}/\tilde{u} \rightarrow \tilde{B}$	$jj + \ell^+\ell^- \mu^+ \mu^- + E_T$	$M\ell$	X	X
	\tilde{W}	$\ell^+\ell^- \mu^+ \mu^- + E_T$	$M\ell$	X	X
LLE233	$\tilde{t} \rightarrow \tilde{H}$	$b\bar{b}\tau^+\tau^- \ell^+\ell^- + E_T$	$M\ell$	✓	✓
	\tilde{H}	$\tau^+\tau^- \ell^+\ell^- + E_T$	$M\ell$	✓	✓
LQD221	\tilde{g}	$\{\ell^\pm jj\} \{\ell^\pm jj\}$	SS ℓ	X	X
LQD321	$\tilde{t} \rightarrow \tilde{H}$	$\{b\{\tau^+ jj\}\} \{\bar{b}\{\tau^- jj\}\}$	OS τ	✓	✓
LQD232	$\tilde{g} \rightarrow \tilde{t}$	$t\bar{t}\{\mu^+ j\} \{\mu^- j\}$	$M\ell$	X	X
LQD333	\tilde{t}	$\{\tau^+ b\} \{\tau^- b\}$	LQ	✓	✓
UDD212	\tilde{g}	$\{jjj\} \{jjj\}$	Trijet	X	X
	$\tilde{t} \rightarrow \tilde{B}$	$t\bar{t}\{jjj\} \{jjj\}$	$\ell + n \text{ jets}$	✓	X
UDD312	\tilde{t}	$\{jj\} \{jj\}$	Dijet Pairs	✓	X
UDD323	$\tilde{t} \rightarrow \tilde{H}$	$bb\{bbj\} \{bbj\}$	$b\text{-jets}$	✓	✓
LH3	\tilde{H}	$W^+ W^- \tau^+ \tau^-$	$M\ell$	✓	✓

Nat. – A “natural” topology, i.e. stops and higgsinos

3G – RPV coupling compatible with a 3rd generation dominant ansatz

- ▶ All scans chosen to be linear in mass – others in ratio

Multi-lepton

Coupling	Production	Final States	Nat.	3G
LLE122	$\tilde{g}/\tilde{u} \rightarrow \tilde{B}$	$jj + \ell^+\ell^-\mu^+\mu^- + \cancel{E}_T$	X	X
	\tilde{W}	$\ell^+\ell^-\mu^+\mu^- + \cancel{E}_T$	X	X
LLE233	$\tilde{t} \rightarrow \tilde{H}$	$b\bar{b}\tau^+\tau^-\ell^+\ell^- + \cancel{E}_T$	\checkmark	\checkmark
	\tilde{H}	$\tau^+\tau^-\ell^+\ell^- + \cancel{E}_T$	\checkmark	\checkmark
LQD232	$\tilde{g} \rightarrow \tilde{t}$	$t\bar{t}\{\mu^+j\}\{\mu^-j\}$	X	X
LH3	\tilde{H}	$W^+W^-\tau^+\tau^-$	\checkmark	\checkmark

- ▶ Multi-leptons \Rightarrow excellent for LLE, LH or some LQD signatures
- ▶ Several signal benchmarks – but one search

Resonances

Coupling	Production	Final States	Search	Nat.	3G
$LQD221$	\tilde{g}	$\{\ell^\pm jj\} \{\ell^\pm jj\}$	$SS\ell$	X	X
$LQD333$	\tilde{t}	$\{\tau^+ b\} \{\tau^- b\}$	LQ	\checkmark	\checkmark
$UDD212$	\tilde{g} $\tilde{t} \rightarrow \tilde{B}$	$\{jjj\} \{jjj\}$ $t\bar{t}\{jjj\} \{jjj\}$	Trijet $\ell + n$ jets	X \checkmark	X X
$UDD312$	\tilde{t}	$\{jj\} \{jj\}$	Dijet Pairs	\checkmark	X

- ▶ LQD and UDD often have no $\cancel{E}_T \Rightarrow$ Resonances
- ▶ A few 7 and 8 TeV searches exist – difficult to reinterpret
 - ▶ Limits on $\tilde{g} \rightarrow \tilde{B} \rightarrow \{jjj\}$ or $\tilde{g} \rightarrow \tilde{t} \rightarrow \{jj\}$?
 - ▶ Include other objects ($\tilde{g} \rightarrow \tilde{t} t \rightarrow t\{jj\}$)
 - ▶ b -tagged, e.g. $\{jb\}$ and $\{jbb\}$

??? – top-like

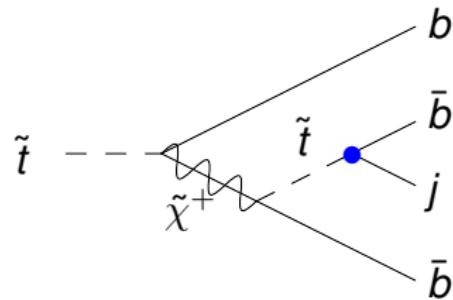
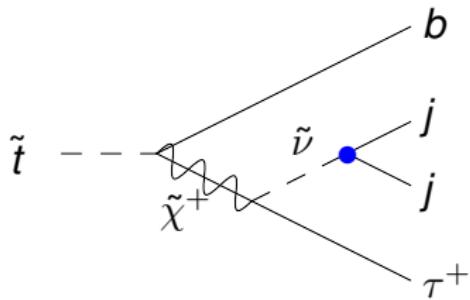
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- ▶ Forget about LHC future...

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- ▶ Forget about LHC future...
- ▶ No LHC searches cover these well-motivated scenarios!!!
- ▶ Completely natural topologies!
- ▶ Have top-like final states (top + X backgrounds)



Summary

- ▶ RPV can be hiding natural topologies
- ▶ Many RPV benchmarks for Snowmass
 - ▶ Many, many more possible RPV signatures
 - ▶ Want to study them? Great!
- ▶ Many motivated signatures still not explored at 8 TeV!
 - ▶ Notably, anything displaced
- ▶ Background studies are in process
- ▶ More volunteers wanted!